AN APPLICATION OF A NARROW SLOT CUT IN THE GROUND TO IMPROVE MULTI-BAND OPERATION OF A SMALL ANTENNA

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Introduction. In general, small size multi-band antennas for hand held phones have to operate at low frequency bands below 1GHz and at upper frequency bands, which are in the vicinity of 2GHz and 5.5 GHz. When the desired number of resonances is generated in a small antenna, normally a lot of research effort must be spent on achieving the required bandwidth properties usually expressed in terms of impedance match and radiation efficiency. To cope with this problem, we have been investigating a modification, which concerns the introduction of a slot cut in the ground plane supporting a small size antenna. Here, we investigate the effect of various shapes of slot cuts on the impedance properties and radiation pattern of a modified antenna. As the introduction of a slot in the ground plane raises concern to increasing radiation towards the user, this problem is also examined.

Exploring the benefits offered by slots in the ground. It goes without saying that the design of an internal antenna for a hand held phone must involve consideration of a ground plane, which plays an active role in the radiating process. Modifying the shape or texture of the ground affects the distribution of surface currents, which in turn modify the antenna performance. In particular, incorporating cut slots in the ground can have a pronounced effect. Here, both theoretical and experimental investigations are undertaken to investigate the effects of slot cuts in the ground on performance of small size antennas.

Results. Due to the presence of the handset battery and the PCB, the investigations concentrate on the slot cuts, which are almost entirely accommodated below the antenna element. In general, the slot can be fully accommodated in the ground or it can cut the edge and then penetrate the ground area. When the slot cuts the edge it can either add more bands or – most likely – broaden existing ones.

Fixed shape slot cuts. Our first investigation concerns antennas with fixed slots cuts. The investigated antenna is planar, single probe fed with a short connecting the element and the ground. This antenna element is supported by a shaped ground plane and the actual ground surface took only 55% of the 114 x 50 mm area. The invented antenna element is within the 50x24x7 mm volume. Figure 1 shows the results for return losses of this antenna when a 60 mm long slot is cut in the ground. As seen in the Figure, by using this slot cut it was possible to obtain a two-band operation of the antenna. The 10dB return loss bandwidth for the lower band, between 820 and 915 MHz, is 95MHz wide. The upper band features a

0-7803-8197-1/03/$17.00 (c)2003 IEEE

considerably greater 10dB bandwidth which is between 1645 MHz and 2500 MHz. It has to be noted that if the permissible RL level was set at 5 dB, the upper band would be 1306 MHz wide, which is equivalent to 62%. Such properties enable to provide several mobile and wireless systems allocated between 1710 and 2500 MHz. It is worthwhile to note that without the slot cut in the ground it was impossible to generate any useful resonances in the frequency range of up to 3000 MHz.

Figure 2 shows four shapes of a slot cut in the ground that were studied next. Using these shapes of slots we were able to obtain multi-resonant operation of the investigated antenna. The use of any of the four slots provided one ultrawide band (at least a 500 MHz frequency range of a good impedance match, entirely located below 2500 MHz).

Figure 3 includes the return loss characteristic for a small PIFA antenna placed above the ground plate which has a slot that cuts the side edge of the ground (the ground outline corresponds to 0.16 x 0.07 λ_0 of the longest wavelength supported by this antenna). For the purpose of comparison, the Figure also presents the characteristic for an antenna having a ground without any slot.

Variable shape slot cuts. Using RF or MEMS switches connected across the slots in the ground plane brings possibility of realizing small size antennas with variable performance (with the slot activated or deactivated by the MEMS switch). In one antenna we observed that switching at the slot end changed the bandwidth of the lowest resonance by 70 MHz and improved the quality of impedance match in the ultrawide band by 2 dB on average.

Backward Radiation Due to Slot Cuts. One of the main concerns related to incorporating slot cuts in the ground plane of an internal antenna is the possibility of increasing radiation towards the operator. Studies of the radiation patterns prove that the radiation of such antennas must be investigated concurrently for the co- and cross-polar. In many instances, the combined power of these orthogonal field components for different spatial coordinates does not display abrupt variations. In our research on the spatial distribution of radiation we have observed that there is no preferred direction of the radiation propagating towards the user for frequency bands below 1000 MHz when slots or cuts are inserted in the grounds. For upper bands above 1000 MHz, the strongest radiation can occur towards the user, but such effect is also observed in antennas with solid plate grounds. Discussing the nulls in the radiation pattern, it is worth recalling that the electromagnetic field in the close vicinity of the radiation source resembles a plane wave irrespective of the nulls and sidelobes occurring in the far-field.

Conclusions. This paper has reported on the use of slot cuts in the ground plane to improve the multi-band operation of small size antennas, such as is required in the present generation of hand held cellular phones. It has been shown that the use of suitable slot cuts can significantly improve the return loss bandwidths of various bands in the multi-band handsets. The use of such slot cuts does not require increasing the size of the antenna or ground plane. Also the use of slot cuts allows for incorporating MEMS switches across the slots to achieve the antenna's variable performance during its multi-band operation. Use of MEMS switches is simple on printed boards.

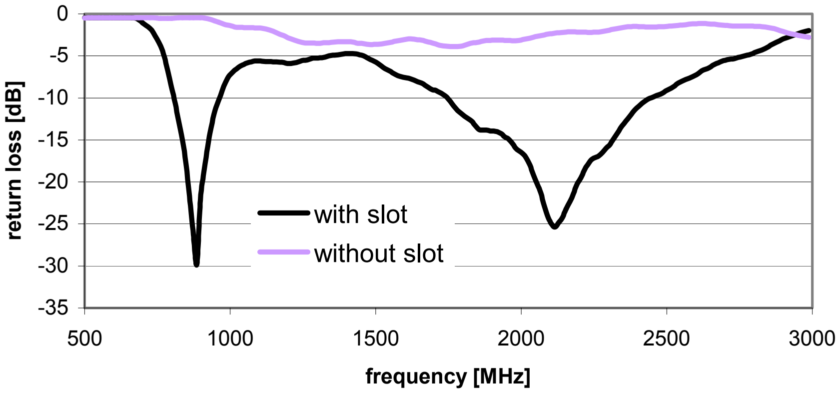

Fig. 1. Measured characteristic of impedance match for the wideband miniature antenna involving a long slot cut beginning at the ground edge.

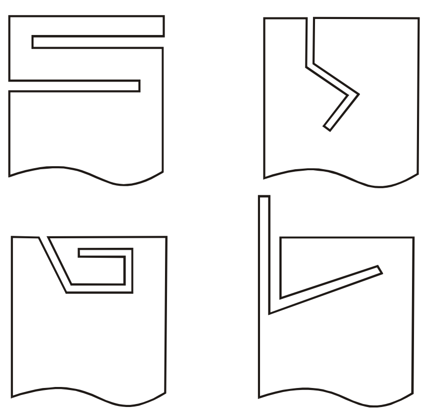

Fig. 2. Four shapes of a slot cut in the ground that may substantially improve the bandwidth properties of small antennas.

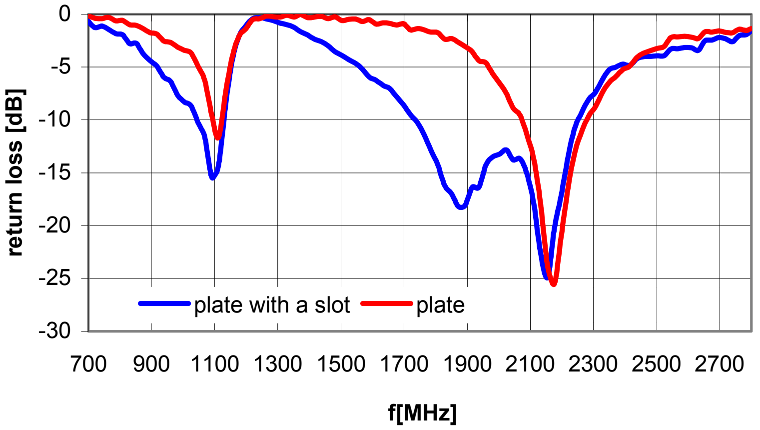

Fig. 3. Measured return loss of a small antenna suspended above the miniature ground plate; the antenna element and the ground are modified with a slot cut arranged along their longer side.

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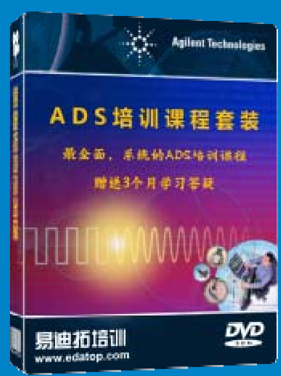

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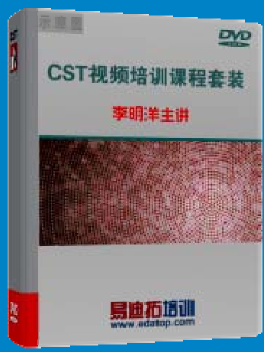

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